# DESIGNING A SECURE AND INTELLIGENT PUBLIC DISTRIBUTION SYSTEM USING BLOCKCHAIN TECHNOLOGY AND DEEP LEARNING

**A SYNOPSIS**

*Submitted by*

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## 1. INTRODUCTION

Blockchain technology has emerged as a transformative force in the digital realm, revolutionizing financial transactions with unparalleled levels of security and transparency. Introduced in 2009 by Satoshi Nakamoto, Bitcoin was the pioneering virtual currency to utilize blockchain technology, paving the way for a multitude of other cryptocurrencies with unique characteristics and capabilities. These digital currencies have reshaped the landscape of digital finance, presenting both opportunities and challenges, and driving further research and development into blockchain applications.

At its core, blockchain technology is a distributed, decentralized ledger system that ensures transparency and secure record-keeping. Its ability to facilitate record-sharing among stakeholders and maintain an authentic transaction history has made it an attractive option across various sectors. One area where blockchain technology holds significant promise is in Public Distribution Systems (PDS). Established in 1947 to provide the population with affordable access to essential commodities, PDS schemes can benefit from the integration of blockchain technology to enhance transparency and eliminate potential illicit activities during the distribution process.

Blockchain operates as a decentralized ledger system that records transactions across a network of computers. Each transaction is confirmed by multiple network nodes and added to a block of transactions, creating a chronological and immutable record of all transactions. This ensures that the information stored on the blockchain is secure, transparent, and tamper-proof. Because blockchain is decentralized, no single entity controls the network, making it resistant to fraud and censorship. This technology provides an efficient and transparent way to record and verify transactions, with the potential to revolutionize several industries. The process of blockchain technology is illustrated in Figure 1.

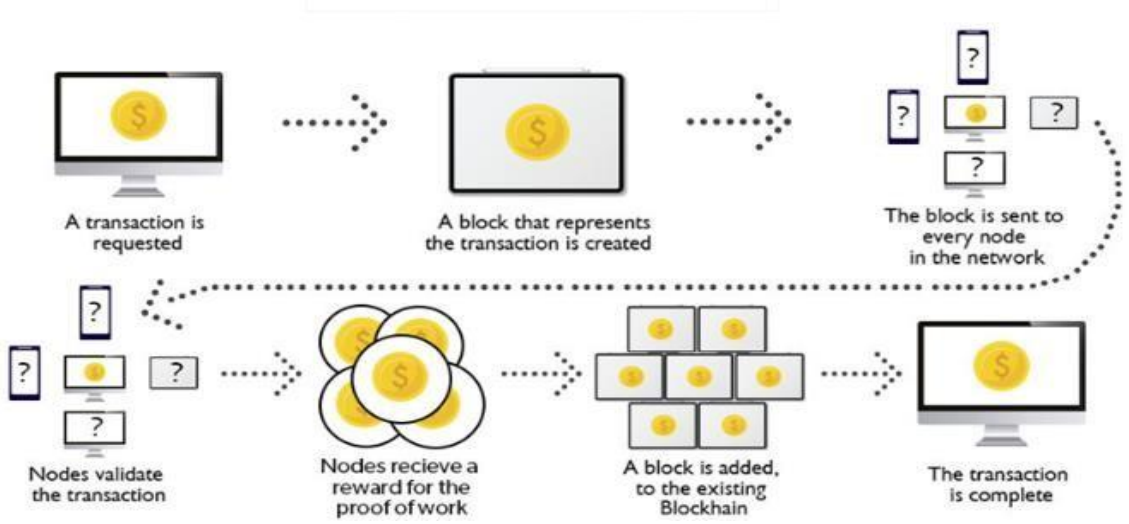

A transaction is requested
A block that represents the transaction is created
The block is sent to every node in the network
Nodes validate the transaction
Nodes recieve a reward for the proof of work
A block is added, to the existing Blockhain
The transaction is complete

**Figure.1. The working process of blockchain technology**

Ensuring food safety is a vital global issue, focusing on providing consistent access to nutritious, safe, and affordable food for everyone to maintain a healthy lifestyle [1]. In India, the Public Distribution System (PDS) is designed to deliver essential commodities and agricultural products to disadvantaged communities. However, the PDS faces significant challenges, including inefficiencies in identifying recipients, wastage, and complex procedures [2].

A strong Public Distribution System should embody key features such as effective information sharing, reliable outcomes, data protection, integrity, and simplicity [3]. Blockchain technology, with its decentralized and secure ledger system, plays a crucial role in addressing these needs by recording and safeguarding irreversible data from online transactions. This Distributed Ledger Technology (DLT) ensures that transactions are authenticated through decentralization and cryptographic hashing mechanisms [4], [5]. On the Ethereum blockchain, transactions are securely agreed upon by both parties to ensure confidentiality and authenticity. Access to the distributed system is governed by a digital contract, and each business transaction is recorded in a block with the relevant information. Before being added to the network, each block is validated using a smart contract.

Once validated, blockchain technology employs robust encryption algorithms to secure and protect the data. A key advantage of blockchain innovation is its ability to ensure privacy and prevent unauthorized alterations to transaction records, especially since much of the collected information is stored in a shared manner [6]. Unlike centralized systems, which are susceptible to cyber-attacks, blockchain enhances data confidentiality and integrity through decentralization and cryptographic hashing, making it more reliable and trustworthy than traditional record-keeping methods. Implementing smart contracts in conventional methods improves performance and reduces operational costs. However, a notable drawback of blockchain technology is its high electricity consumption needed to maintain a legitimate distributed ledger [7]. Despite this, blockchain significantly impacts the data science industry, especially in managing and processing raw data [8].

Various data analytics approaches are crucial for extracting valuable insights from past distribution data, which is essential for the Public Distribution System (PDS) to develop effective future strategies. These strategies include forecasting commodity needs and managing the allocation of additional commodities. Machine Learning (ML) techniques, such as data analysis and categorization, can be used to evaluate historical PDS data. Modern ML methods allow for the creation of reliable and adaptable forecasting models that predict future outcomes based on newly acquired information [9]. Prediction methods are key components of any ML system, enabling organizations to anticipate future needs based on inferred data. In computer technology, Deep Learning (DL) techniques, particularly Deep Neural Networks (DNNs), have introduced a new class of algorithms with diverse applications. DNNs are among the most powerful DL models, enhancing feature representation in learning models and providing a more advanced alternative to traditional methodologies [10].

The PDS is a highly complex and fragmented system with partial integration and numerous

intermediaries, leading to an inefficient operational environment. The effectiveness of food security initiatives is further compromised by poor handling, inadequate infrastructure, and insufficient marketing facilities. These challenges create significant barriers to achieving sustainable food security. Additionally, the lack of proper oversight in the PDS results in wastage, theft, and corruption, further exacerbating inefficiencies in food distribution. These issues contribute to broader problems such as corruption, malnutrition, and rising poverty levels. Therefore, modernizing the PDS with technology is crucial. Integrating technologies like blockchain into the PDS and similar initiatives can ensure and monitor sustainable food security. Deploying a PDS system on blockchain combined with deep learning technology allows for tracking goods at every stage of distribution and provides predictive analytics for sales forecasting.

## 2. LITERATURE SURVEY

### 2.1 Blockchain in Public Distribution Systems (PDS)

This chapter explores the background research and perspectives on the proposed Secure Intelligent Public Distribution System (SIPDS). The current Public Distribution System (PDS) faces numerous challenges in delivering efficient distribution services, analyzing data, and developing better future strategies. Key issues include data security, data interoperability, and poor record management, all of which require significant improvements to enhance the effectiveness of commodity distribution services. Additionally, it is essential to evaluate PDS data to uncover valuable insights for better decision-making in the future and to showcase the benefits of data analytics. Another critical aspect is ensuring that all electronic transactions among the federal government, state governments, district offices, ration shops, and customers are accurately documented within the system. To address these challenges, researchers are developing reliable and intelligent applications aimed at improving the public distribution system's services.

The advent of blockchain technology has opened new avenues for securely and efficiently managing commodity supply data across distributed networks. The integration of Information and Communication Technologies (ICTs), such as the Internet of Things (IoT), big data analytics, and Artificial Intelligence (AI), into industrial processes enhances decision-making efficiency, accountability, and anti-corruption efforts. These technologies have the potential to revolutionize the entire manufacturing process by increasing the productivity of existing supply chain operations, according to Yeo & Grant [11]. Specifically, wireless networks and Radio Frequency Identification (RFID) can ensure traceability and food safety throughout the distribution process.

Blockchain technology is typically categorized into financial and non-financial applications. In the financial sector, blockchain is used in payment systems, virtual currencies, and financial services,

say Cappa & Pinelli [12], with significant implications for economic assets like fiat currency, securities, financial derivatives, and stock exchanges. Non-financial applications span various industries, including healthcare (e.g., online clinical care, health service administration, personalized medicine, and preventing medication counterfeiting) According to Farouk et al. [13] e-voting, identity and security mechanisms, and corporate sectors like inventory management and authenticity verification, according to Zhu et al. [14]. Numerous studies highlight the benefits of blockchain in production capacity applications, including monitoring and traceability, improved data organization across the supply chain, better stock and process evaluation, and smart transport technologies, as advocated by Behnke & Janssen [15]. Business models based on IoT and blockchain are gaining momentum, enhancing transparency and traceability within supply chain networks, says Kshetri [16].

Furthermore, blockchain technology can detect counterfeit goods in the electronics industry and address the management demands and capabilities of logistics systems, according to Behnke & Janssen [15]. Research studies on blockchain applications in logistics demonstrate a growing interest in data mining techniques across various fields, including healthcare, academia, and financial services. For example, one study Jaroodi & Mohamed [17] has proposed a predictive model for assessing product risks using limited resources, while another study by Mazumdar & Ruj [18] has employed data mining techniques to uncover hidden information and insights from large datasets.

### 2.2 Platforms Utilizing Blockchain Technology

Blockchain technology, which leverages a distributed ledger to store data exchanges securely and reliably, represents a significant technological breakthrough. There are three main types of blockchain architectures: public, private, and consortium. A public blockchain is fully accessible to anyone and typically uses proof-of-work consensus mechanisms. A private blockchain, on the other hand, operates on a chain of permissioned networks managed by a single organization. Consortium or federated blockchains are permissioned networks designed for corporate applications, where multiple organizations collaborate to enhance their operations using blockchain technology, says Kumar [19].

Recent reviews of Agbo et al. [20] indicate that the Ethereum and Hyperledger Fabric frameworks are commonly employed to build corporate applications. According to Sugumaran & Rajaram [21] Ethereum enhances blockchain functionality by supporting and executing smart contracts using high-level programming languages. These features make Ethereum a robust and reliable foundation for creating blockchain-based systems like the Public Distribution System (PDS) as said by Ilakkiya & Rajaram [22]. As a result, the proposed Secure Intelligent Public Distribution System (SIPDS) leverages the Ethereum platform to develop a secure and intelligent public distribution network based on blockchain technology.

### 2.3 Structure of PDS

The Figure 2 illustrates the hierarchical structure of the Public Distribution System (PDS) in India, starting with the Central Government at the top, which formulates policies and allocates food grains. The Food Corporation of India (FCI) procures, stores, and transports these grains to the state governments. The state governments then oversee the intra-state distribution, managing the flow down to the district administrations. The districts ensure that the food grains reach the local ration shops, which are the retail outlets where the end beneficiaries, primarily economically weaker sections, purchase the subsidized food grains.

The PDS operates through a systematic flow from the central level to the grassroots level, ensuring food security for the underprivileged. Ration shops, also known as fair price shops, play a crucial role in this system, as they are the points where customers access the food grains. This structure ensures that the food grains are distributed efficiently, making essential commodities accessible to those in need.

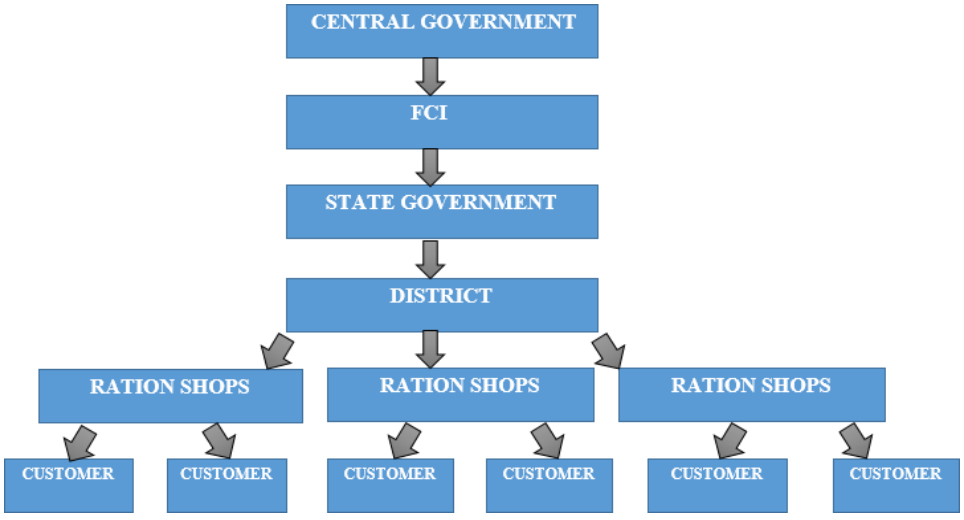



**Figure.2. The Structure of the Public Distribution System (PDS) in India**

## 3. PROBLEM STATEMENT & OBJECTIVES

### 3.1 Problem Statement

The Public Distribution System (PDS) is essential for fighting poverty and ensuring food security. However, it faces significant issues with transparency, security, and efficiency. To address these challenges, this study proposes the usage of blockchain technology. The key components ofthe study include developing a blockchain system with Solidity to automate food delivery transactions and creating a decentralized system on the Ethereum network using MyEtherWallet to track and manage transactions. This approach aims to streamline operations and improve transparency across the distribution network.

Additionally, the study explores integrating blockchain with MongoDB to enhance

efficiency and build trust within the PDS. It introduces the Secure and Intelligent Public Distribution System (SIPDS), a blockchain-based solution that combines data security and predictive analytics to forecast demand. By leveraging blockchain technology, the study seeks to improve the overall transparency, security, and efficiency of food distribution, benefiting all stakeholders involved. This innovative approach promises to make the PDS more reliable and effective, ensuring fair and accountable distribution of resources and strengthening food security initiatives.

### 3.2.Objectives

The main aim of this research is to revolutionize the Public Distribution System (PDS) by enhancing transparency, security, and efficiency using blockchain technology. The following are the specific objectives:

- **Objective 1**: To implement a decentralized public distribution system on the ethereum blockchain using MyEtherWallet.
- **Objective 2**: To design an efficient public distribution system utilizing the ethereum blockchain and MongoDB.
- **Objective 3**: To find the best technique for forecasting the demand in PDS.

## 4. PROPOSED METHODOLOGY

The proposed methodology for revolutionizing the Public Distribution System (PDS) with blockchain technology involves a comprehensive approach. Initially, a detailed system architecture will be developed, integrating blockchain with the existing PDS framework using Solidity to create smart contracts for automating food delivery transactions. This blockchain-based system will be implemented on the Ethereum network with MyEtherWallet, ensuring secure and transparent transaction records among various stakeholders. MongoDB will be integrated to manage and store transaction data efficiently, handling large volumes of data with fast retrieval and processing. Additionally, the Secure and Intelligent Public Distribution System (SIPDS) will be developed, leveraging blockchain for data security and employing predictive analytics and deep learning techniques to forecast demand and optimize resource allocation. The performance of this new system will be evaluated in terms of transparency, security, and efficiency, comparing it with the existing PDS to identify significant improvements and benefits for all stakeholders.

### 4.1 Implement a decentralized public distribution system on the ethereum blockchain using MyEtherWallet

Blockchain technology is an innovative platform that offers distributed ledgers with decentralized and transparent transmission mechanisms, applicable across various industries. In this work, we propose a future innovation for the Public Distribution System utilizing the

blockchain platform. Our proposal involves a decentralized Public Distribution System on the Ethereum network, using Solidity language, and interacting with MyEtherWallet, which offers extensive features and functionality. This blockchain-based application is designed to record all transactions between involved parties. This paper focuses on food transactions involving the central government, state governments, district-level offices, retail ration stores, and consumers.

### 4.1.1. Integration of Ethereum Smart Contracts and MyEtherWallet in Public Distribution System

In the proposed decentralized Public Distribution System (PDS), Ethereum smart contracts and MyEtherWallet (MEW) are integral components that enhance security, transparency, and efficiency. Ethereum smart contracts, which are self-executing agreements with the terms directly written into code, ensure that transactions between the central government, state governments, district offices, retail ration stores, and consumers are automatically enforced and recorded on the blockchain. These smart contracts eliminate intermediaries, reduce fraud, and streamline the distribution process.

MyEtherWallet, a user-friendly interface for interacting with the Ethereum blockchain, allows consumers and other stakeholders to securely manage their accounts, perform transactions, and interact with smart contracts. By using MEW, participants in the PDS can verify and track their transactions in real-time, ensuring accountability and trust throughout the distribution chain. This integration of Ethereum smart contracts and MEW significantly modernizes the PDS, providing a robust framework for a transparent and efficient distribution of resources.

### 4.1.2 Workflow of Decentralized Public Distribution System (PDS) Using Blockchain

The decentralized Public Distribution System (PDS) workflow begins with users interacting with MyEtherWallet, a widely-used Ethereum wallet. Through MyEtherWallet, users can manage their Ethereum accounts and initiate transactions. These transactions are executed on the Ethereum blockchain, ensuring both transparency and security. The Food Corporation of India (FCI), representing the central government, distributes food supplies to the state governments, whichthen allocate them to districts. The district-level offices further distribute the supplies to the retail rationshops, which finally provide the goods to consumers. Each transaction in this chain, from the central government to the consumer, is recorded on the blockchain using smart contracts, creatingan immutable and transparent record of the entire distribution process. The workflow is illustratedin Figure 3.

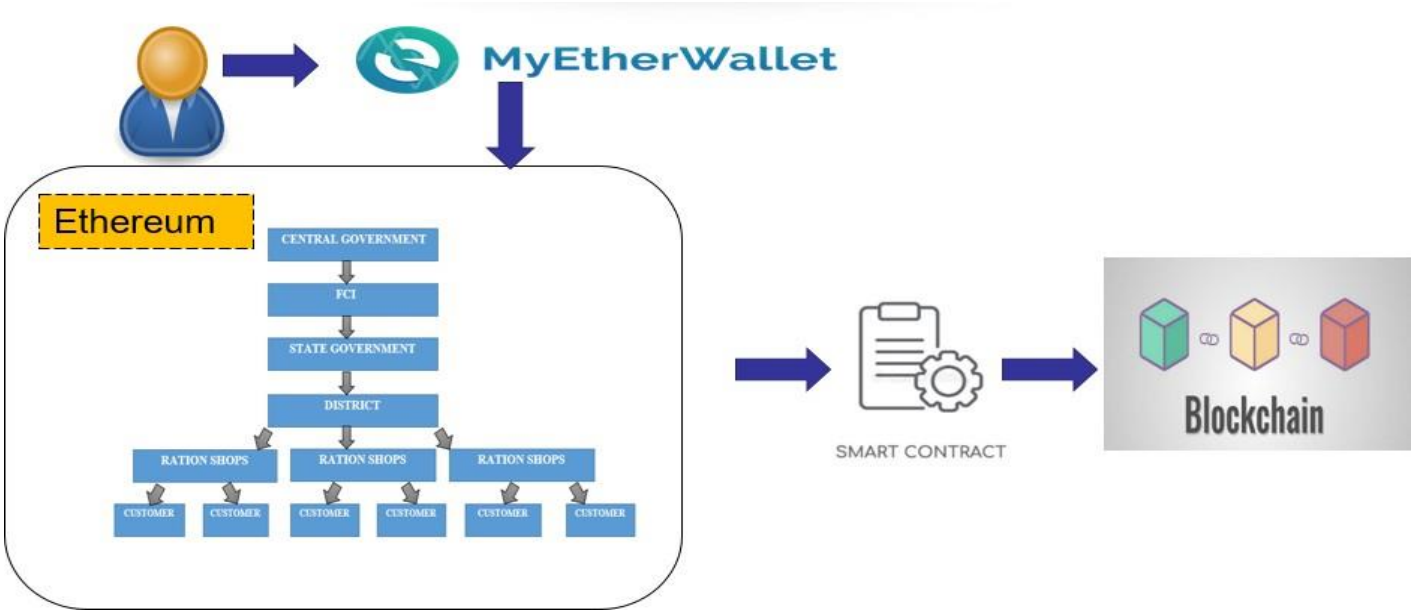



**Figure.3. Workflow of the proposed system**

### 4.1.3 Experimental analysis

The experimental analysis demonstrates the impact of integrating MyEtherWallet on the execution times of various transactions within the Public Distribution System (PDS). The transactions analyzed include Commodity Details, Component Details, Procurement Details, Add Customer Details, and Distribution Details to other Components. The results, as shown in Figure 4, indicate that MyEtherWallet integration are execution times are low and show a consistency when compared to the aspects without MyEtherWallet.

**Figure.4. Execution time comparison**

The experimental analysis also includes a comparison of transaction costs in Gwei with and without the integration of MyEtherWallet. Figure 5 illustrates the transaction cost evaluations for various transactions in the Public Distribution System (PDS). The data reveals that the costs are significantly lower with MyEtherWallet integration across all transaction types. This reduction in transaction costs demonstrates the cost-efficiency benefits of using MyEtherWallet in the PDS.

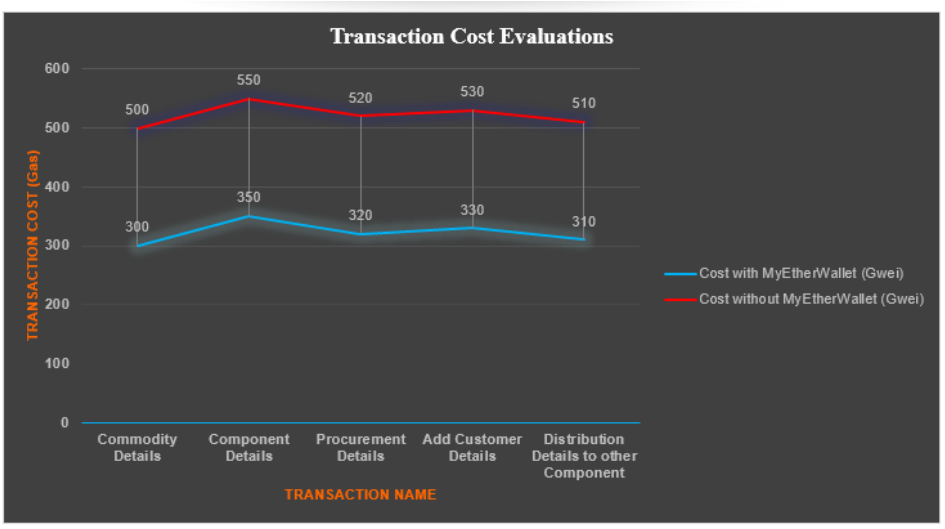



**Figure.5. Transaction cost evaluations**

Table 1 compares various research works on Public Distribution System, focusing on blockchain implementation, smart contract usage, efficiency, and security. It highlights that while some studies have not incorporated blockchain technology, the proposed work uses Ethereum and smart contracts, achieving higher efficiency and stronger security when compared to the other research studies.

**Table 1 Comparison of Some Existing Blockchain Implementations**

| RESEARCH WORK | TECHNIQUES USED | BLOCKCHAIN | IMPLEMENTATION | SMART CONTRACT | EFFICIENCY | SECURITY |
|---|---|---|---|---|---|---|
| S. Ølnes, et al. [21] | Provides a decentralized and immutable record of transactions to enhance transparency and data integrity. | No | - | - | Moderate | Weak |
| Tian, F [22] | Tracks and traces products using wireless identification tags. | Yes | Yes | No | Low | Moderate |
| S. Huh & S. Cho [23] | Secures and verifies interactions between IoT devices in a decentralized manner. | Yes | - | Yes | Low | Weak |
| M. Warkentin & C. Orgero [24] | Evaluates blockchain based on its ability to protect data privacy, ensure accuracy, and maintain accessibility. | Yes | - | - | Low | Weak |
| PDS using Blockchain with MyEtherWallet | Interface for interacting with the Ethereum blockchain and managing digital assets. | Yes | Ethereum | Yes | High | Strong |

### 4.2 Design an efficient public distribution system utilizing the ethereum blockchain and MongoDB

This study explores the feasibility of using blockchain technology to eliminate inefficiencies and enhance trust in the PDS framework by integrating blockchain with MongoDB. A comprehensive web-based system, encompassing the essential features and functions to manage interactions among the central government, state governments, district offices, ration shops, and customers is proposed. Consequently, all transactions are recorded on a blockchainnetwork that interconnects these various components. Hence, the proposed system using Ethereum blockchain and a decentralized MongoDB database. Ensuring confidentiality through blockchain technology is one of the standout features of this proposed solution.

#### 4.2.1 Blockchainified MongoDB in Public Distribution Systems

Integrating blockchain technology with MongoDB creates a "blockchainified" database system that significantly enhances the capabilities of Public Distribution Systems (PDS). Blockchain ensures that all transactions are securely recorded and immutable, providing a tamper-proof history of activities. MongoDB, known for its scalability and flexibility, efficiently stores and organizes these transactions, allowing for easy data retrieval and analysis. This integration ensures that data within the PDS is both secure and accessible, improving transparency and trust in the system.

The key features of blockchainified MongoDB include enhanced security, data immutability, and decentralization. Blockchain's cryptographic algorithms secure transactions, while MongoDB's encryption capabilities protect data at rest and in transit. The decentralized nature of blockchain reduces the risk of a single point of failure, ensuring the system's resilience. Together, these technologies create a robust and efficient PDS, capable of managing interactions between various stakeholders, including government agencies, ration shops, and customers, with greater confidence and reliability.

#### 4.2.2 Integrating Blockchain with MongoDB in Public Distribution Systems

The integration of blockchain technology with MongoDB in Public Distribution Systems (PDS) aims to enhance transparency, security, and efficiency across various components. Figure 6 shows a blockchainified MongoDB PDS involving the central government, the FCI (Food Corporation of India), the state government, the district offices, the ration shops and customers

Users interact with the PDS through a web application, which connects different PDS components. Transactions, from the central government to customers, are recorded using smart contracts and stored in a blockchain network supported by MongoDB. This setup ensures all transactions are securely documented, immutable, and easily retrievable, enhancing the trust and reliability of the system.

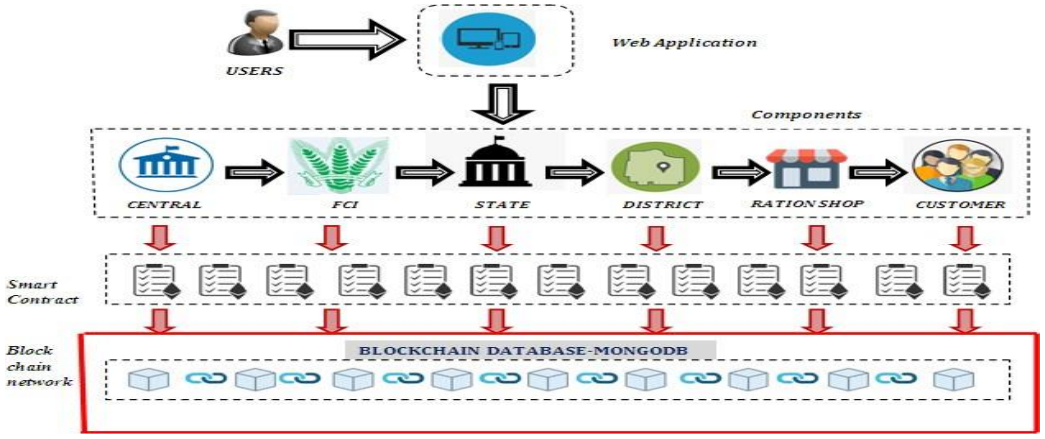



**Figure.6. Blockchain-Integrated Public Distribution System with MongoDB**

### 4.2.3 Experimental analysis

Figure 7 compares the transaction costs and execution costs over 50 blocks for different PDS activities: Add Procurement Activity, Distributeto FCI Activity, FCI to States, States to Districts, Districts to Ration Shops, and Ration Shops toCustomers. Each chart shows fluctuating costs for both transaction and execution across the blocks.

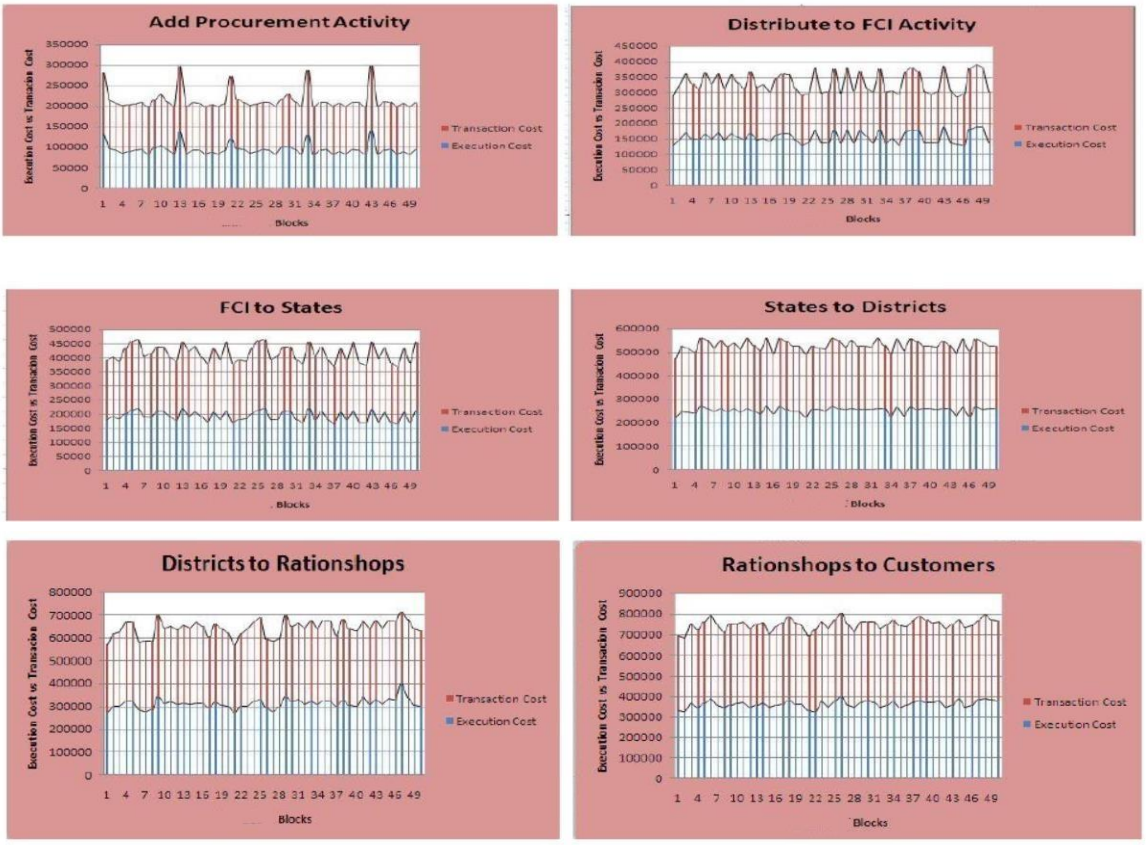



**Figure.7. Public Distribution System activity costs comparison**

Figure 8 compares the performance of four database systems— Blockchain with Blockchain without MongoDB, Blockchain with MySQL and Blockchain without MySQL— across five types of transactions: Commodity Details, Component Details, Procurement Details, Add Customer Details and Distribution Details to other Components. Performance is measured in milliseconds, with each transaction type showing different response times for the three database systems. The data shows that the times are significantly lower for Blockchain with MongoDB integration across all transaction types. This reduction in block creation time highlights the cost-efficiency benefits of using Blockchain with MongoDB in the PDS.

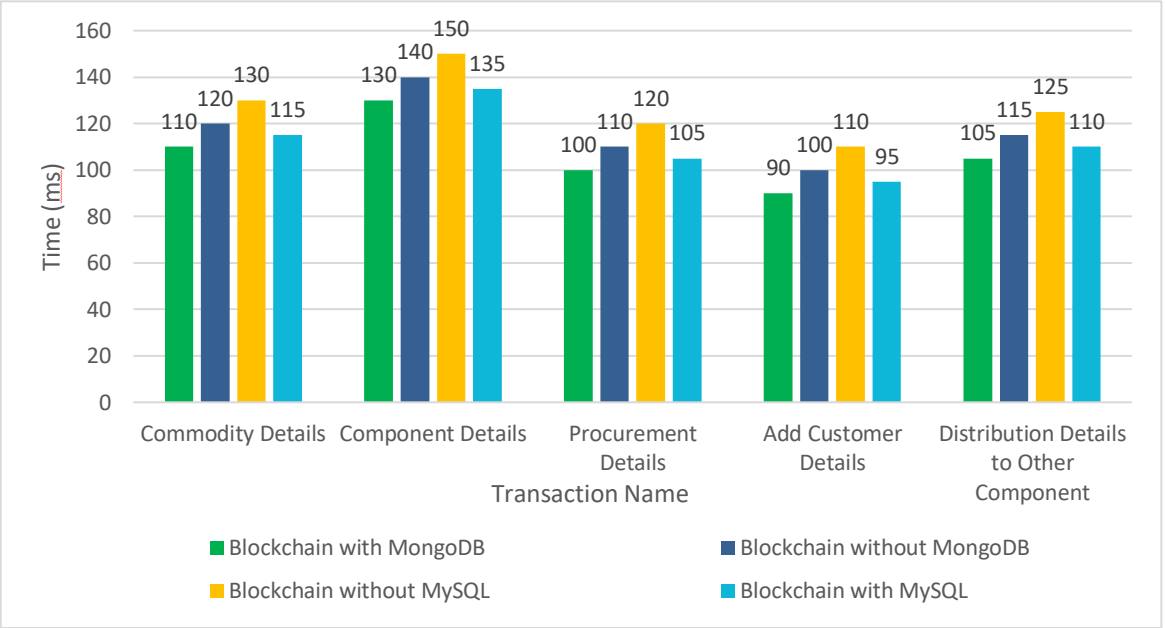



**Figure.8. Database Performance Comparison**

Table 2 highlights how different research works address various aspects of blockchain technology, including their use of smart contracts, efficiency, security, and scalability, and whether they use permissioned blockchains. The present study bridges the above mentioned gaps in the existing research.

**Table 2 Blockchain in PDS Comparison**

| RESEARCH WORK | TECHNIQUES USED | SMART CONTRACT | EFFICIENCY | SECURITY | FUNCTIONALITY | SCALABILITY | PERMISSION BLOCKCHAIN |
|---|---|---|---|---|---|---|---|
| A. Andreas et al. [25] | Uses cloud computing for e-government services, focusing on public cloud deployment | No | Medium | Medium | Moderate | Medium | No |
| R. Philipp et al. [26] | Employs blockchain and smart contracts to facilitate and secure collaboration in maritime supply chains. | Yes | Medium | High | Extensive | Medium | Yes |
| S. Saberi et al. [27] | Integrates blockchain for improving sustainability, transparency, and traceability in supply chain management. | Yes | Medium | Medium | Moderate | Medium | Yes |
| S. Wang et al. [28] | Implements a blockchain framework with fine-grained access control for secure data sharing in decentralized storage systems. | Yes | Low | High | Extensive | High | Yes |
| Blockchain in PDS with MongoDB | Utilizes Ethereum-based blockchain with MongoDB for managing decentralized public distribution systems (PDS). | Yes | High | High | Extensive | High | Yes |

### 4.3 To find the best model for demand forecasting based on deep learning techniques

This study introduces the Secure and Intelligent Public Distribution System (SIPDS), an innovative framework that combines blockchain technology, smart contracts, and deep learning to optimize public distribution processes. The SIPDS features a dual approach: securing distribution data through blockchain and employing predictive analytics to enhance forecasting. By using Ethereum for a secure foundation and integrating advanced blockchain tools for smart contracts and predictions, the system analyzes historical data from the Public Distribution System (PDS) to identify patterns and develop a robust prediction model. The model's accuracy is evaluated using metrics such as Mean Absolute Error (MAE), Root Mean Squared Error (RMSE), and $R^2$ score, ensuring the SIPDS provides reliable and actionable insights to improve distribution efficiency and decision-making.

#### 4.3.1 Dual Approach: Blockchain Security and Predictive Analytics

1. **Blockchain-Based Security:** The first approach utilizes blockchain technology to ensure the security and integrity of distribution data. By leveraging Ethereum and smart contracts, the system creates an immutable ledger that records every transaction and data update. This ensures that all distribution activities are transparent, tamper-proof, and automatically compliant with the predefined rules. The use of blockchain guarantees the

security of data from unauthorized changes and provides a reliable record of distribution processes.

2. **Predictive Analytics for Forecasting:** The second approach focuses on enhancing forecasting through advanced predictive analytics using deep learning models. The system employs a combination of Long Short-Term Memory (LSTM), Bidirectional LSTM (BiLSTM), and Gated Recurrent Unit (GRU) models to analyze historical data and generate accurate forecasts.
    - **LSTM**: Captures long-term dependencies in time-series data by using memory cells to store and recall information over long periods. It is effective in identifying trends and patterns in historical data.

$$h_t = o_t \odot \tanh(C_t)$$

    - **BiLSTM**: Enhances forecasting by processing data in both forward and backward directions, capturing context from both the past and the future. This bidirectional approach improves the model's ability to understand data patterns.

$$h_t = (1 - z_t) \odot h_{t-1} + z_t \odot \tilde{h}_t$$

    - **GRU**: Provides a streamlined alternative to LSTM by using update and reset gates to efficiently manage long-term dependencies and improve processing speed. It is well-suited for handling large datasets.

$$h_t = [\text{Forward LSTM}_t; \text{Backward LSTM}_t]$$

Together, these predictive models work to enhance the accuracy of forecasts, enabling betterdecision-making based on historical data trends.

### 4.3.2 Integrating Blockchain and Analytics for Efficient Commodity Distribution

Figure 9 presents a system that utilizes Ethereum blockchain technology to manageand analyze the distribution of commodities in a hierarchical chain. Starting from the central government, the distribution flows down through the Food Corporation of India (FCI), the state governments, the districts, and finally to the ration shops, which is turn serve the customers directly. This hierarchical structure ensures a systematic and organized distribution process.

Data analytics is employed to perform time series, component, and commodity-wise analysis of the distribution data. Predictive analytics techniques such as LSTM, GRU, and Bi-LSTM are used to forecast future trends and demands. Smart contracts on the blockchain ensure transparency and efficiency in transactions, making the entire system more reliable and accountable.

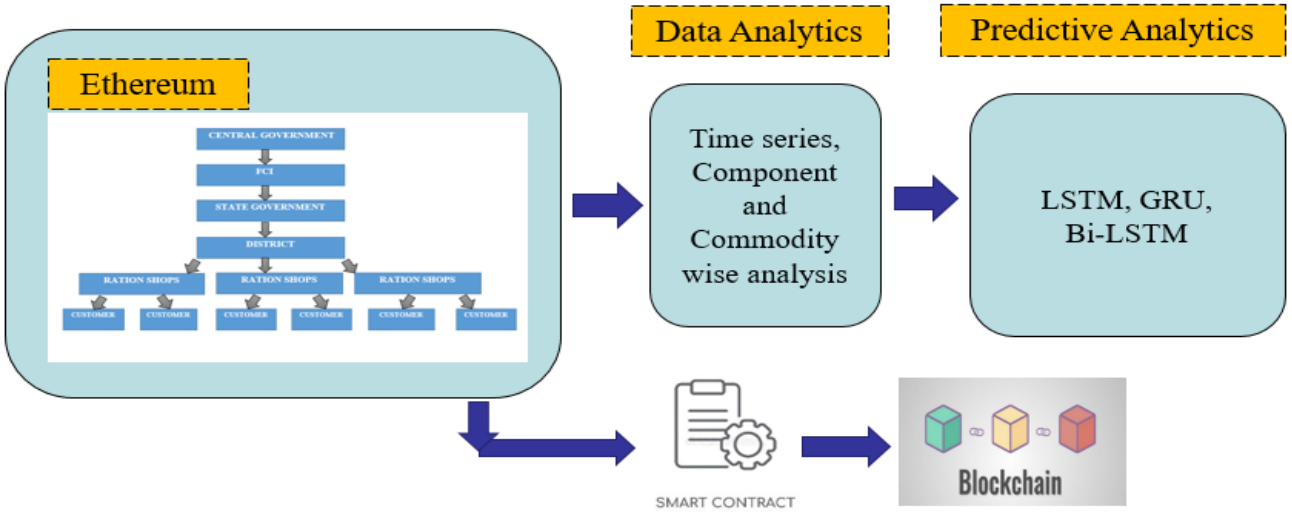



**Figure.9. Integration of blockchain and analytics for efficient commodity distribution**

### 4.3.3 Experimental analysis

Figure 10 consists shows the analysis of commodity allotment and distributionfrom 2019 to 2021. The charts show day-wise fluctuations in allotment quantity over a month and month-wise variations over a year. They also depict the distribution of different commoditieson a daily basis and reveal the monthly distribution trends. These visualizations provide comprehensive insights into the patterns and trends in commodity allotment and distribution, facilitating effective data analysis and informed decision-making.

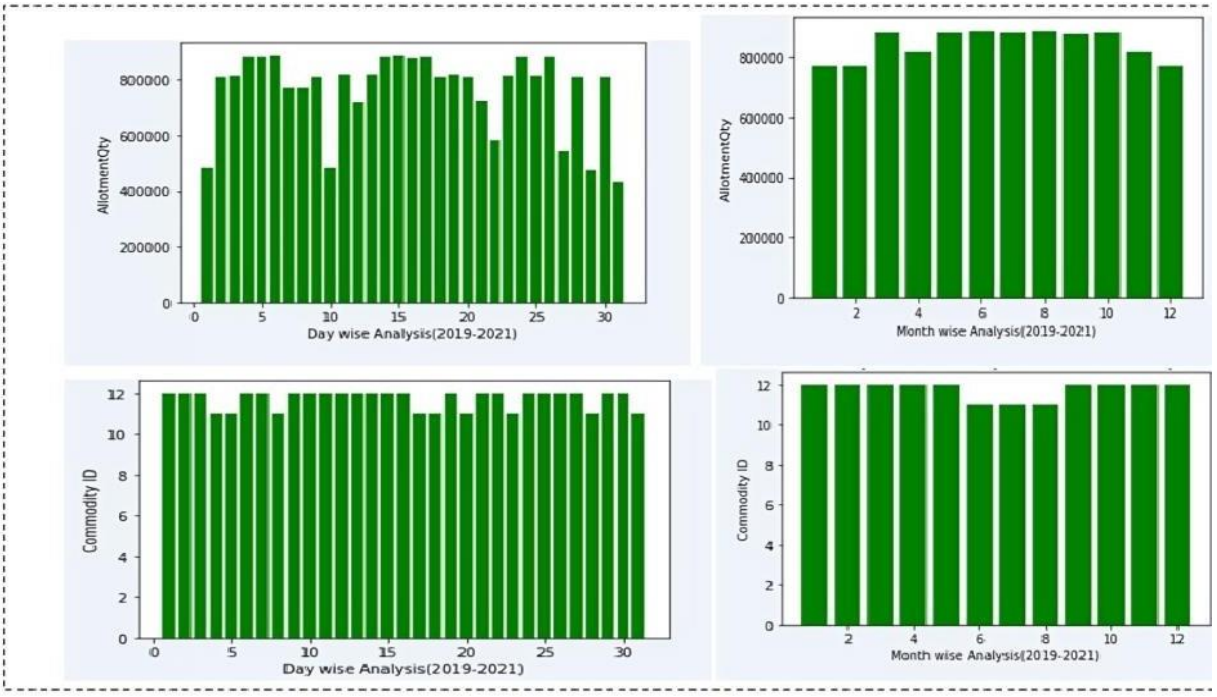
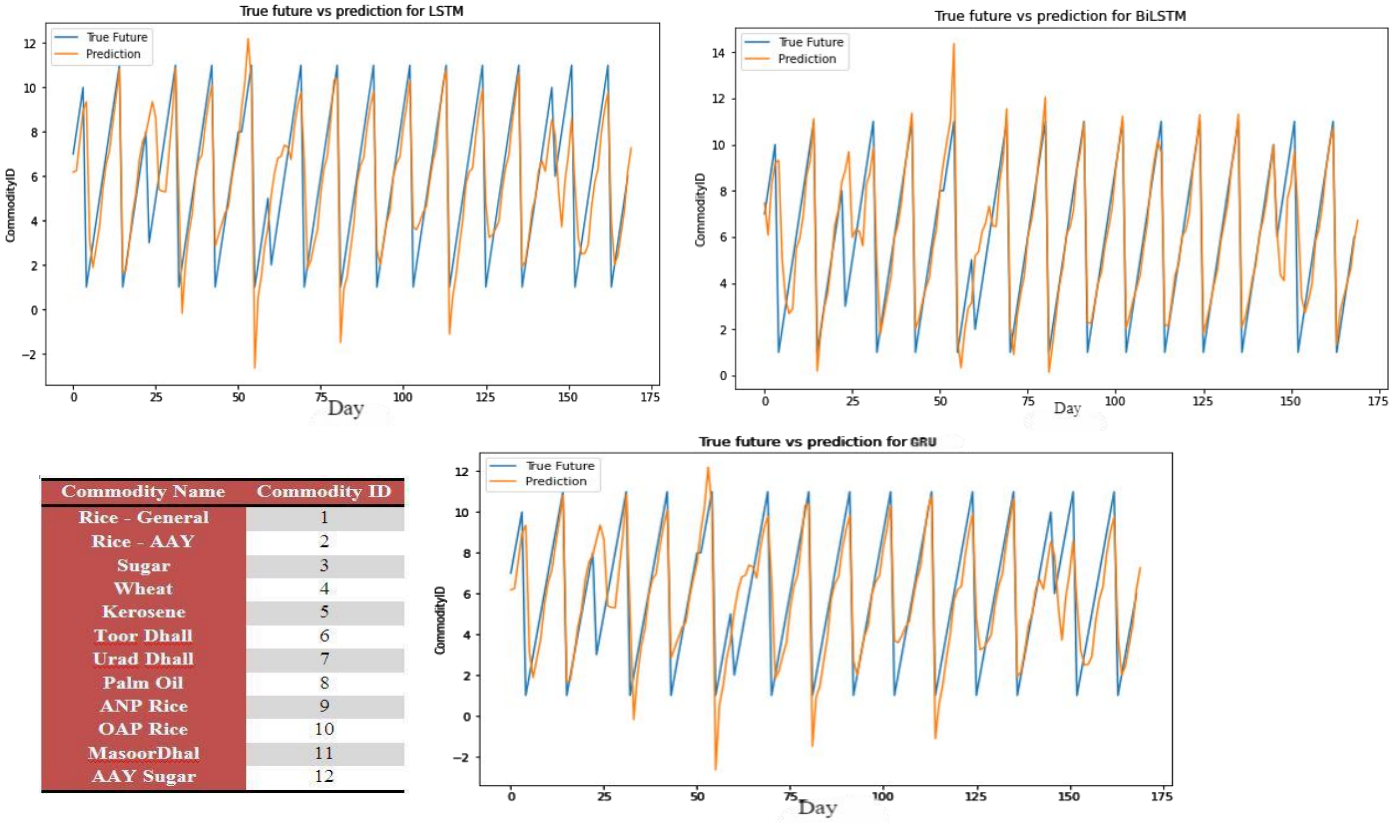



**Figure.10. Analysis of commodity allotment and distribution**

Figure 11 displays three graphs, compare the future values with the predicted values using LSTM, GRU and Bi-LSTM models. The blue lines represent the future values, while theorange lines represent the predictions. These graphs predict the future demands of the commodity.




| Commodity Name | Commodity ID |
|---|---|
| Rice - General | 1 |
| Rice - AAY | 2 |
| Sugar | 3 |
| Wheat | 4 |
| Kerosene | 5 |
| Toor Dhall | 6 |
| Urad Dhall | 7 |
| Palm Oil | 8 |
| ANP Rice | 9 |
| OAP Rice | 10 |
| MasoorDhal | 11 |
| AAY Sugar | 12 |

**Figure.11. Comparative analysis of commodity sales prediction using BiLSTM, LSTM and GRU**

Figure 12 displays three graphs compare the future values with the predicted values using LSTM, GRU and Bi-LSTM models. The blue lines represent the future values, while theorange lines represent the predictions. These graphs predict the quantity distributed from one component to the other in future.

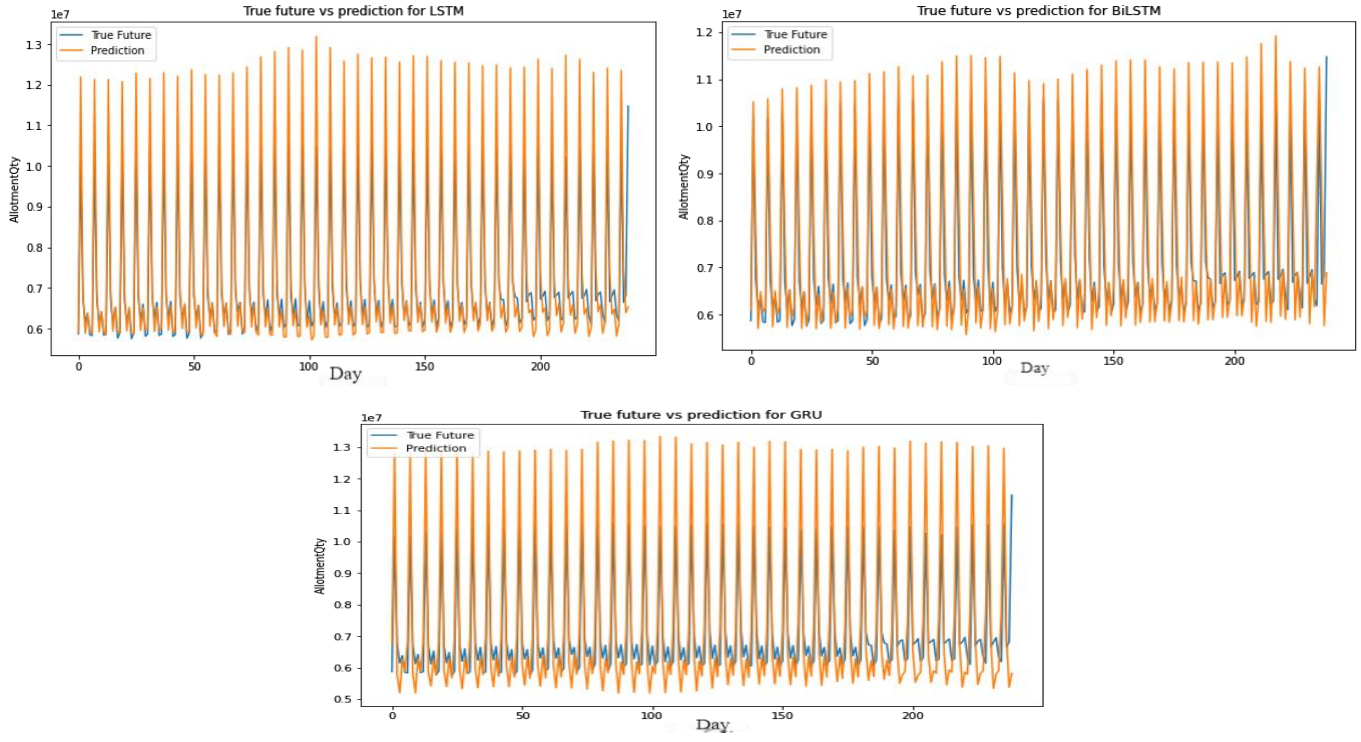



**Figure.12. Comparative analysis of quantity sales prediction using BiLSTM, LSTM and GRU**

Table 3 presents a performance comparison of different deep learning models (BiLSTM, LSTM, and GRU) for predicting various metrics across different commodity distribution and quantity allotment scenarios. The metrics used to evaluate the models are MAE (Mean Absolute Error),RMSE (Root Mean Squared Error), and $R^2$ score. Hence, BiLSTM model have exhibited a better performance across different scenarios and analysis.

**Table 3** Model Performance for Commodity Distribution and Allotment Analysis

| COMMODITY WISE ANALYSIS | DL TECHNIQUES | MAE | RMSE | $R^2$ SCORE |
|---|---|---|---|---|
| **Distribute to FCI, Tamilnadu** | BiLSTM | 1.097 | 1.467 | 0.90 |
| | LSTM | 2.545 | 2.998 | 0.80 |
| | GRU | 1.645 | 2.934 | 0.83 |
| **To Districts** | BiLSTM | 1.236 | 2.954 | 0.92 |
| | LSTM | 2.897 | 2.986 | 0.86 |
| | GRU | 1.878 | 2.998 | 0.85 |
| **To Taulks and ration shops** | BiLSTM | 2.478 | 2.923 | 0.91 |
| | LSTM | 2.567 | 2.978 | 0.86 |
| | GRU | 2.659 | 2.989 | 0.84 |
| **ALLOTMENT QUANTITY WISE ANALYSIS** | **DL TECHNIQUES** | **MAE** | **RMSE** | **$R^2$ SCORE** |
| **Distribute to FCI, Tamilnadu** | BiLSTM | 1.432 | 1.643 | 0.95 |
| | LSTM | 2.094 | 2.153 | 0.89 |
| | GRU | 2.673 | 2.543 | 0.85 |
| **To Districts** | BiLSTM | 1.634 | 1.234 | 0.94 |
| | LSTM | 3.564 | 2.456 | 0.85 |
| | GRU | 2.456 | 3.097 | 0.86 |
| **To Taulks and ration shops** | BiLSTM | 2.345 | 2.087 | 0.96 |
| | LSTM | 2.897 | 3.897 | 0.86 |
| | GRU | 3.675 | 3.097 | 0.84 |

Table 4 compares various research works on blockchain implementation in PDS, highlighting their use of smart contracts, frameworks, efficiency, and security. Thus exhibiting a highly satisfied result, among all research studies.

**Table 4** Blockchain in PDS Comparison

| SYSTEM | SMART CONTRACT | FRAMEWORK | EFFICIENCY | BLOCKCHAIN NETWORK | FUNCTIONALITY |
|---|---|---|---|---|---|
| **V. R. Sugumaran & A. Rajaram [29]** | Yes | Hyperledger Sawtooth | Low | Permissioned | Track the location of commodities |
| **N. Ilakkiya & A. Rajaram [30]** | No | Node.js | Low | Permissioned | Built small web-based applications |
| **S. Sooraj et al. [31]** | Yes | Hyperledger fabric with big data | High | Permissioned | Conceptual framework for storage and analysis of data across on-chain and off-chain |
| **Asmath Fahima Famnaz & Sharmila Kumari [32]** | Yes | Ethereum & Remix IDE (Online Tool) | Low | Permissioned | Develop only smart contract-based application |
| **S. K. Singh et al. [33]** | Yes | Hyperledger Composer | Low | Permissioned | To achieve the strategic goal of a transparent and trusted Food Subsidy Distribution System |
| **Proposed SIPDS** | Yes | Ethereum | High | Permissioned | SIPDS including commodity details, distribution records, etc. Smart contract-enabled data and predictive analytics |

## 5. CONCLUSION

The traditional Public Distribution System (PDS) faces significant challenges, including security issues, lack of transparency, and corruption, which undermine consumer trust and affect beneficiaries. To address these issues, a decentralized PDS is proposed using the Ethereum network, integrating Solidity and MyEtherWallet for secure transaction recording. The efficiency of blockchain in improving PDS is further explored by incorporating MongoDB in a web-based model that connects various government systems, ensuring all transactions are securely recorded. The Secure and Intelligent Public Distribution System (SIPDS) on the Ethereum platform uses smart contracts and deep learning to analyze PDS data, identify patterns, and forecast resource demand. This predictive ability helps optimize resource allocation, ensuring accurate distribution of food grains, benefiting both the government and end-users.

## 6. ORGANIZATION OF THESIS

**Chapter-1: Introduction -** This chapter introduces blockchain technology and its potential to improve the Public Distribution System (PDS). It outlines the problem the research aims to solve, thetechnologies involved, and the significance and potential impact of the study.

**Chapter-2: Literature Review -** This chapter reviews existing research on blockchain applications in PDS. It highlights various approaches, identifies gaps in current research, and explains how this study aims to address these gaps.

**Chapter-3: Implementing a Decentralized Public Distribution System on the Ethereum Blockchain with MyEtherWallet -** This chapter proposes using Ethereum to decentralize PDS. It explores tracking transactions across different government and retail levels using tools like Solidity and MyEtherWallet to enhance accountability and security.

**Chapter-4: Designing an Efficient Public Distribution System Utilizing Ethereum Blockchain and MongoDB -** This chapter evaluates integrating blockchain with MongoDB to improve PDS efficiency. It involves developing a web-based system to manage transactions and interactions across various stakeholders, aiming to build trust and security.

**Chapter-5: Finding the best technique for forecasting the demand in PDS -** This chapter introduces the Secure and Intelligent Public Distribution System (SIPDS), a blockchain framework designed to enhance the efficiency of PDS. SIPDS uses blockchain for data security and predictive analytics for smarter decision-making.

**Chapter-6: Conclusion and Future Work -** The final chapter summarizes the research findings, discusses their implications, and suggests directions for future research to further improve blockchain-based PDS.

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